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**Collins**

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(54) **ADAPTIVE DEFROST CONTROL DEVICE AND METHOD**

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(51) **Int. Cl.**<sup>7</sup> ..... **F25D 21/06; F25D 21/00**

(52) **U.S. Cl.** ..... **62/156; 62/234**

(58) **Field of Search** ..... **62/156, 234, 151, 62/153, 155, 80**

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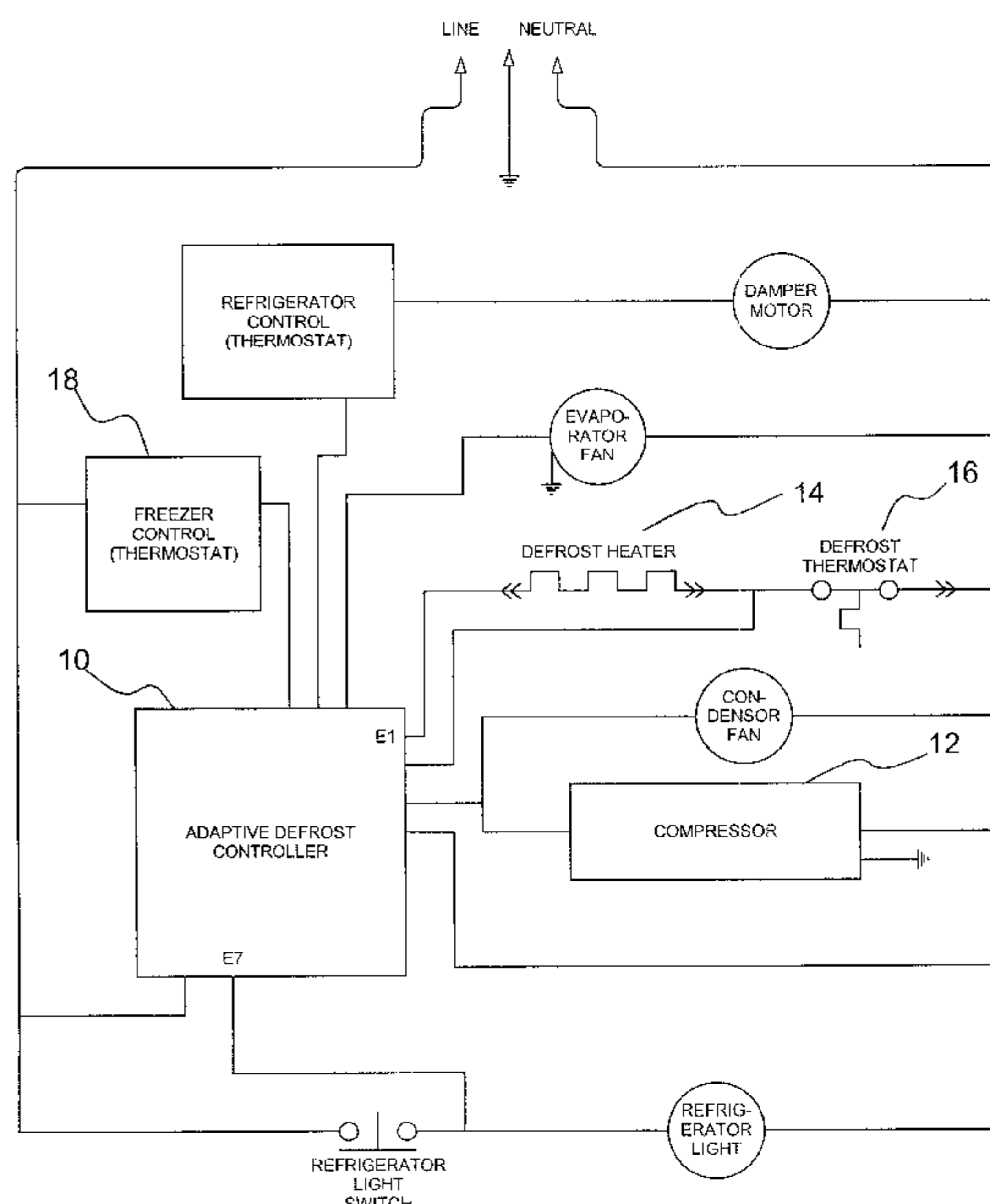
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(57) **ABSTRACT**

Adaptive defrost control and method for a household refrigerator wherein a defrost interval is adjusted based upon the time it takes for a previous defrost cycle to complete. The adaptive defrost control also provides a vacation mode in which the defrost interval is set to an artificially long interval if a door of refrigerator has not been opened for some predetermined period of time. Further a defrost termination thermostat is provided that is stable during power interruption. The termination thermostat is used as a memory device to determine whether a defrost cycle was in process when power was interrupted.

**10 Claims, 4 Drawing Sheets**



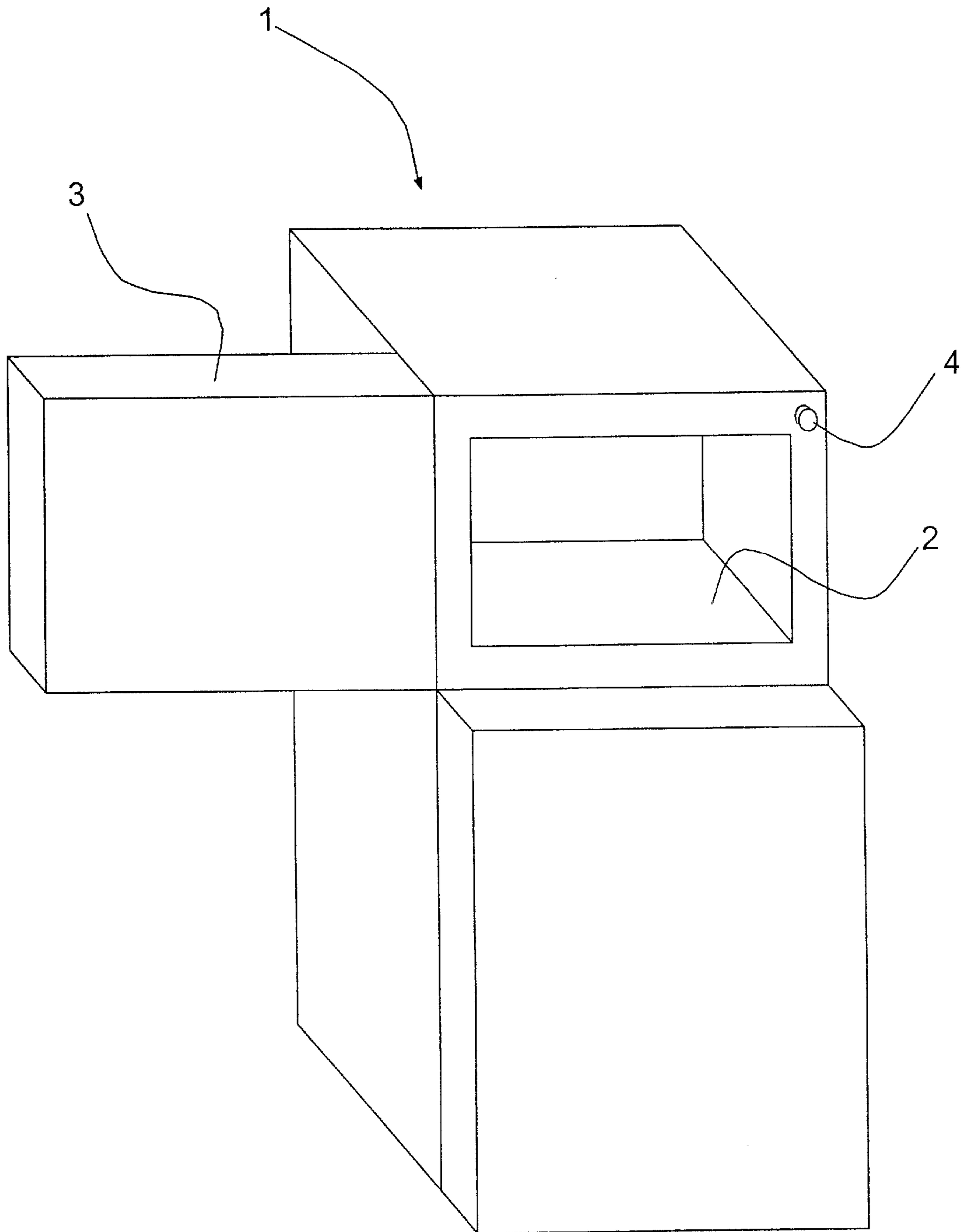


FIG. 1

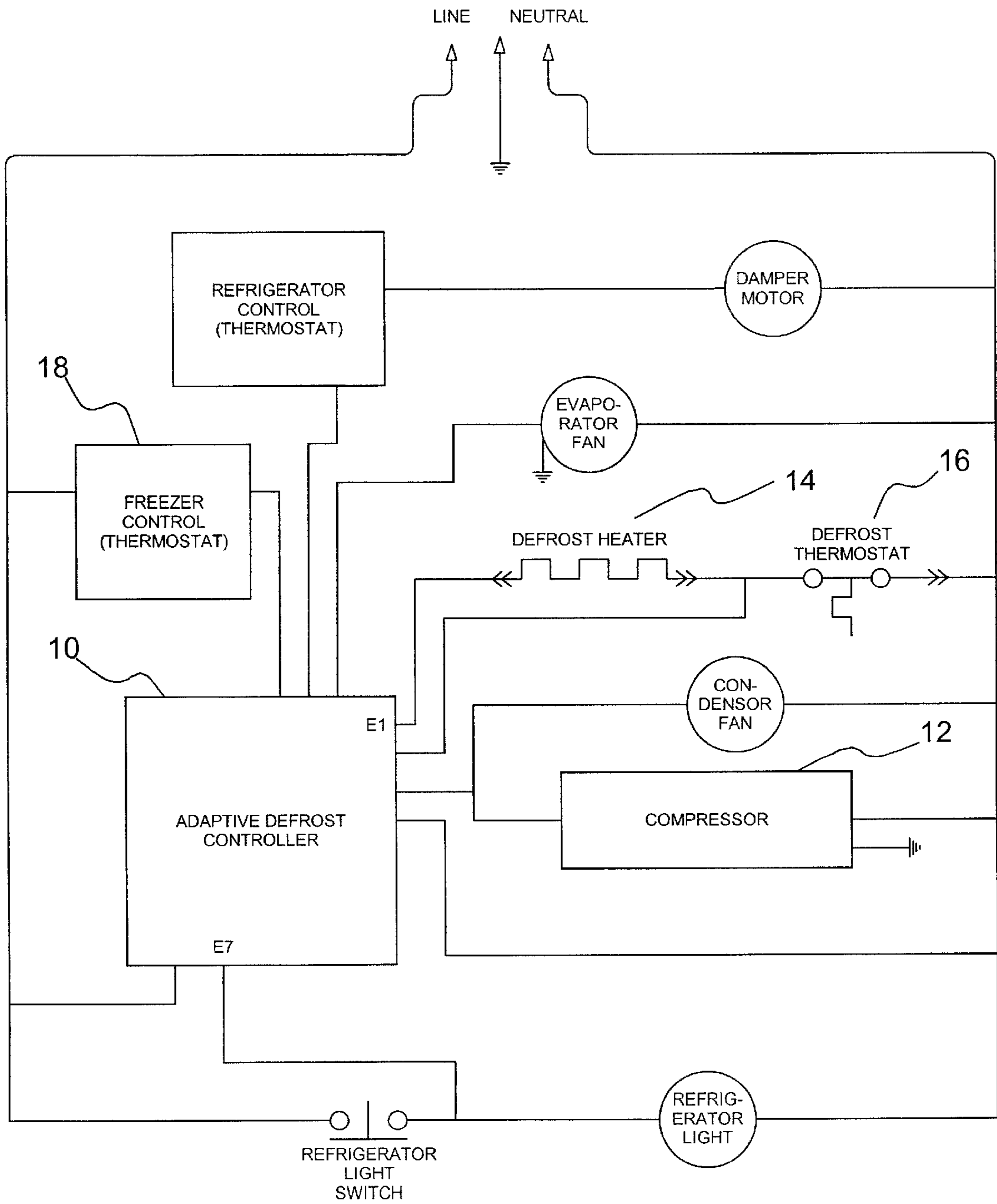


FIG. 2

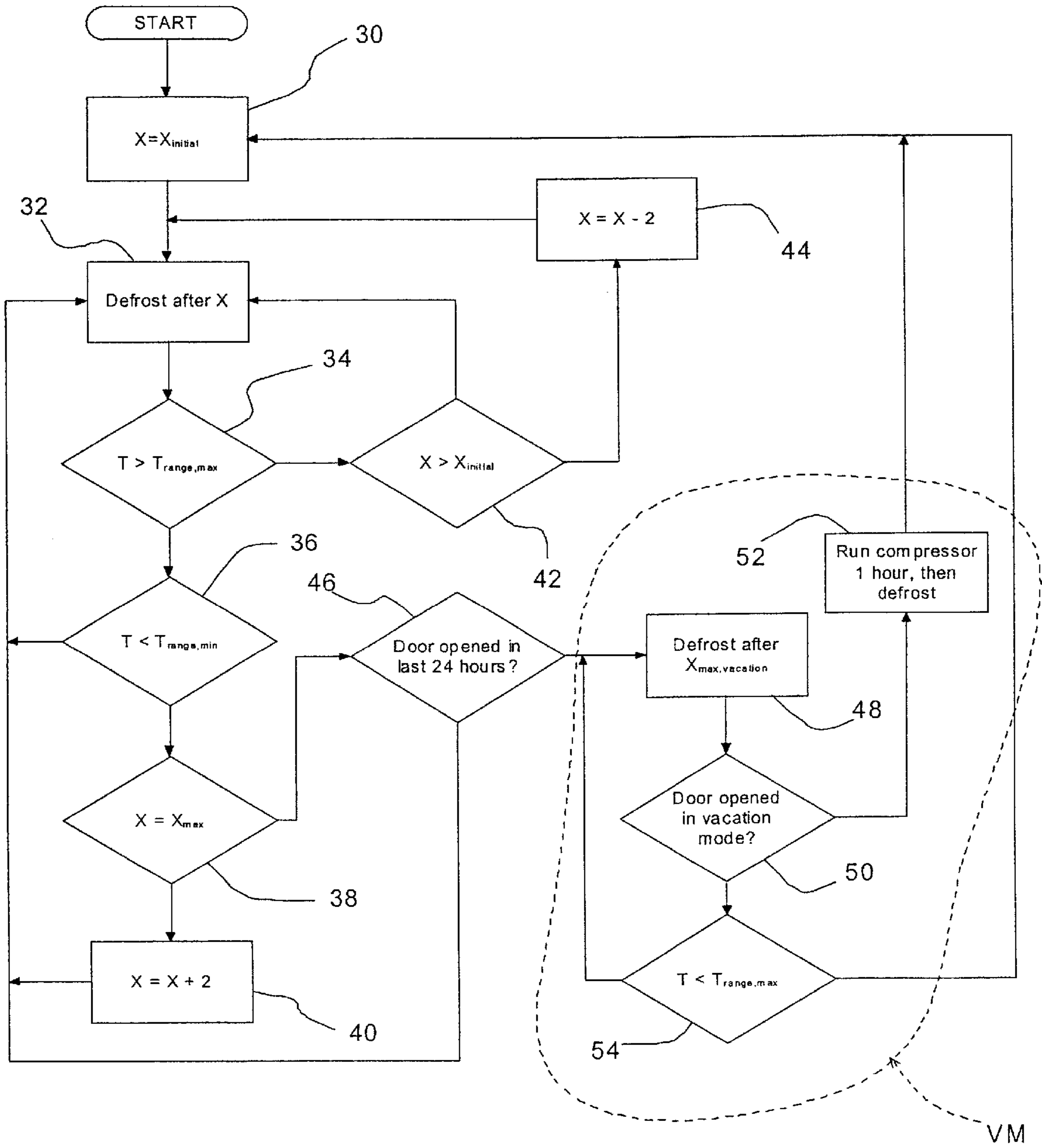


FIG. 3

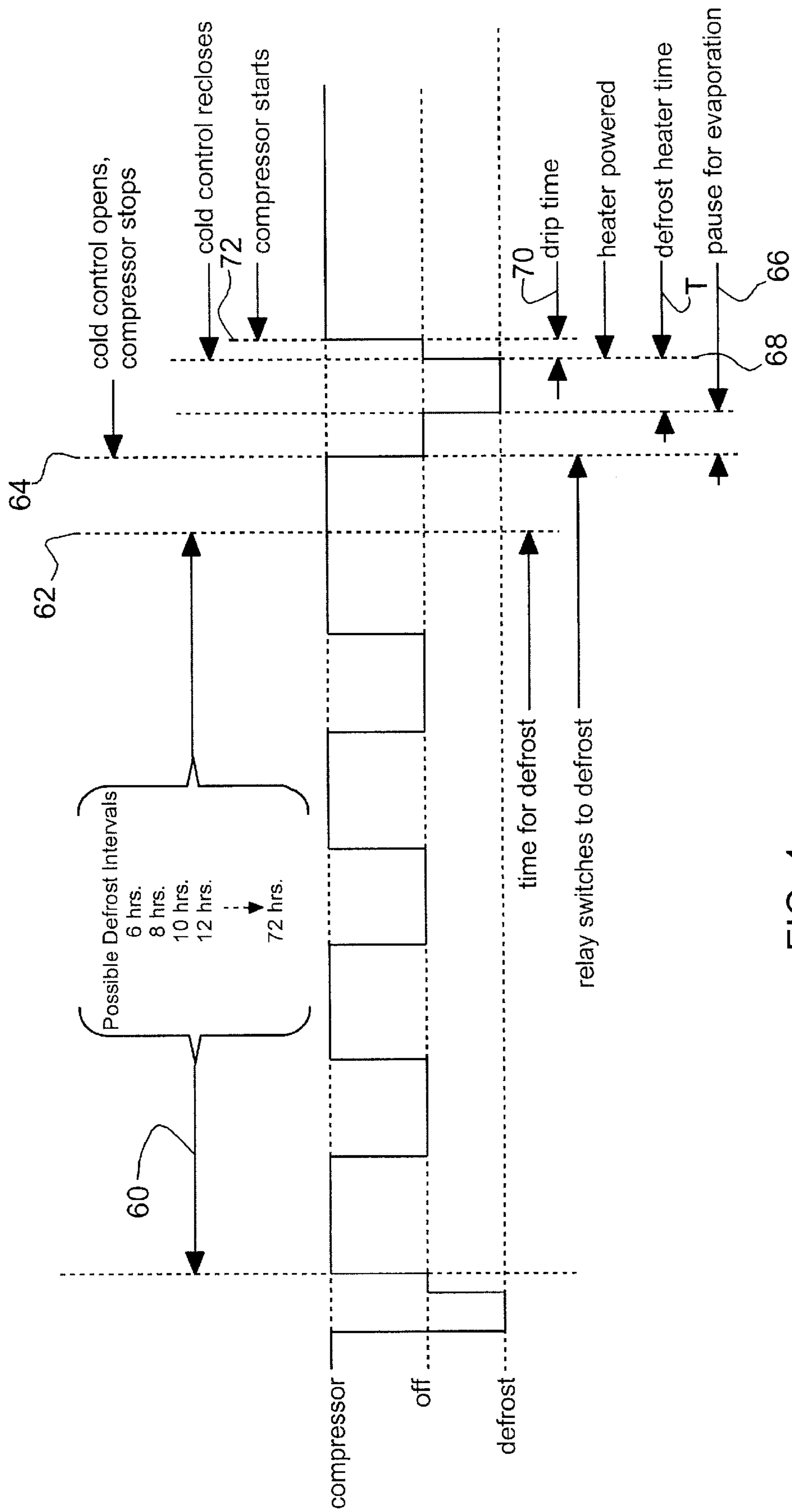


FIG. 4

## ADAPTIVE DEFROST CONTROL DEVICE AND METHOD

### CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application Ser. No. 60/280,072 filed Mar. 30, 2001.

### BACKGROUND OF THE INVENTION

The present invention relates generally to the control of a defrost heater for a refrigerator and specifically to an adaptive control method and apparatus therefor.

It is known to provide a defrost heater to a refrigeration unit such as in a domestic refrigerator or freezer appliance. In conventional arrangements, the heater is cycled on the basis of electromechanical timers which accumulate time on the basis of compressor run time. When the timer accumulates a predetermined amount of compressor run time, the defrost heater initiates a defrost cycle, regardless of the current state of various refrigeration components and environment. This can lead to an inefficient use of energy.

### BRIEF SUMMARY OF THE INVENTION

According to an aspect of the present invention, a method for defrosting a household refrigeration appliance including a compressor and a refrigeration compartment having a door is provided. Said method comprises steps of:

- setting a defrost interval (X) to an predetermined initial value ( $X_{initial}$ );
- initiating a defrost cycle after the defrost interval has elapsed and the compressor is not running;
- after initiating said defrost cycle, terminating said defrost cycle as determined by a defrost termination thermostat, the period between initiating and terminating the defrost cycle being referred to as a defrost time (T);
- decreasing said defrost interval (X) by a set amount if said defrost time (T) is greater than a set ideal maximum defrost time ( $T_{range, max}$ ); and
- increasing said defrost interval (X) by a set amount if said defrost time (T) is less than a set ideal minimum defrost time ( $T_{range, min}$ ).

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a refrigerator embodying an adaptive defrost control of the present invention;

FIG. 2 is a schematic view of the electrical connections of a refrigerator embodying the adaptive control of the present invention;

FIG. 3 is a flow diagram for a method of performing an adaptive defrost control according to an embodiment of the present invention; and

FIG. 4 is a timing chart illustrating various steps of a method of performing an adaptive defrost control according to an embodiment of the present invention.

### DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a refrigerator 1 having a freezer compartment 2. The freezer compartment 2 is provided with a door 3 having a switch 4 which monitors the condition of the door 3, either open or closed.

FIG. 2 shows an wiring schematic for the refrigerator 1 which comprises an adaptive defrost controller 10, a com-

pressor 12, and a defrost heater 14. The defrost heater 14 is provided to defrost the freezer compartment 2 of the refrigerator 1 (see FIG. 1). The controller 10 is programmed to control the defrost heater to carry out the present invention, as described below. In a sense, the controller 10 does the job of the electromechanical timer in the prior art, accumulating compressor run time until it has accumulated an amount of time equal to a set defrost interval, X. At this point the controller 10 indicates that it is time for a defrost cycle.

However, the controller 10 is also programmed to adjust the value of the defrost interval X, based upon certain operating conditions. In order to reduce the above described waste of energy, the adaptive defrost controller 10 monitors the defrost time and adjusts the defrost time interval accordingly.

The algorithm shown in FIG. 3 illustrates one embodiment for adjustment of the heater cycle time, X according to the present invention. First, the defrost interval X is set to be equal to a minimum or initial defrost interval,  $X_{initial}$ , such as 6 hours (step 30). After the controller 10 has accumulated X hours, a defrost cycle is initiated (step 32).

A defrost termination thermostat or controller 16 (FIG. 2) turns off the heater when sufficient defrosting has occurred. Meanwhile, the controller 10 stores the duration of the defrost cycle or defrost time, T.  $T_{range}$  defines the time limits for an "ideal" defrost time. For example,  $T_{range}$  could be a range of 12 to 16 minutes. If the defrost time, T, is greater than a maximum "ideal" defrost time,  $T_{range, max}$ , or 16 minutes, as determined in step 34, then the controller 10 proceeds to step 42. Otherwise, if the defrost time, T, is less than a minimum "ideal" defrost time,  $T_{range, min}$ , or 12 minutes as determined in step 36, then the controller 10 proceeds to step 38. Otherwise, if T is within the "ideal" defrost time,  $T_{range}$ , or between 12 and 16 minutes, then the controller 10 returns to step 32 and waits for the next defrost cycle.

If the controller reaches step 38, then the defrost cycle, T, is too short for maximum efficiency. At this point, if the defrost interval X is already set to a maximum value,  $X_{max}$ , such as 72 hours, then the controller 10 proceeds to step 46. Otherwise, the defrost interval X is incremented by a set increment, such as 2 hours, (step 40) and the controller 10 returns to step 32 and waits for the next defrost cycle. This lengthening of the defrost interval, X, will help to increase the length of the subsequent defrost cycle, T.

If the controller reaches step 42, then the defrost cycle, T, is too long for maximum efficiency. At this point, if the defrost interval, X, is already set to the minimum value,  $X_{initial}$ , then the controller 10 returns to step 32 and waits for the next defrost cycle. If, however, the defrost interval, X, is greater than  $X_{initial}$  then the controller decrements the defrost interval, X, by the set increment, or 2 hours, (step 44) before returning to step 32.

If the controller reaches step 46, then the defrost cycle, T, is too short for maximum efficiency but the defrost time, T, is already at a maximum ideal defrost time,  $T_{range, max}$ , or 16 minutes. If the controller 10 determines by monitoring the door switch 4 at input E7 that the freezer door 3 has not been opened in the preceding 24 hours, vacation mode VM is entered at step 48. Otherwise, the controller 10 returns to step 32 and waits for the next defrost cycle.

Once in vacation mode VM at step 48, the controller waits for a vacation mode time,  $X_{max, vacation}$ , such as 160 hours, initiates a defrost cycle and then proceeds to step 50. At step 50, if the controller determines that the freezer door 3 has been opened while in vacation mode, the controller exits

vacation mode VM via step 52. At step 52, the compressor 12 is run for a predetermined vacation mode exit period, such as one hour, and is followed by a defrost cycle. Following step 52, the controller 10 exits vacation mode VM and proceeds to step 30, resetting X to  $X_{initial}$ .

If the door is not opened at step 50, the controller proceeds to step 54. At step 54, while in vacation mode VM, if the defrost cycle time, T, is below  $T_{range, max}$ , then vacation mode VM is maintained and the controller 10 returns to step 48. If, however, T is equal or greater than  $T_{range, max}$  then the controller exits vacation mode VM directly and proceeds to step 30, resetting X to  $X_{initial}$ .

In addition to the above, an absolute maximum amount of time that the defrost heater can be on,  $T_{max}$ , is set. During the defrost cycle, if the controller 10 determines that the heater has been on for  $T_{max}$ , the heater is immediately terminated at output E1, any drip time (explained below) is skipped, and the controller returns to step 30, allowing the compressor to restart immediately at the demand of the compressor thermostat or cold control 18.

FIG. 4 illustrates a defrost delay used in the present invention to avoid applying defrost heat to boil off liquid refrigerant which may be present in an evaporator.

Ordinarily, the compressor uses energy to condense the refrigerant in a condenser, which in turn absorbs heat from refrigeration compartments causing liquid refrigerant to evaporate and thereby cooling the compartments. However, if the defrost heater is energized while the condenser contains liquid refrigerant, such as immediately following a compressor run cycle, this liquid may be evaporated by the defrost heater, rather than by energy absorbed from the refrigeration compartments.

According to the present invention, in order to minimize liquid refrigerant being boiled off by the defrost heater 14, the adaptive defrost controller 10 will not turn on the defrost heater 12 while the compressor thermostat 18 is open, indicating the compressor is running. That is, once the timing algorithm determines it is time for a defrost cycle to occur, the controller pauses and waits for the freezer compartment 2 to become sufficiently cold before starting the heater 14. During this delay, compressed liquid refrigerant in the condenser is re-evaporated by heat energy from the freezer compartment 2, such that the cooling is not allowed to be wasted by the defrost heater 14.

Specifically, as shown by FIG. 4, the defrost cycle is controlled by the controller as follows. The defrost interval, X, is allowed to elapse by accumulation of compressor run time during the cycling on and off of the compressor (step 60). At time 62, the controller 10 determines that it is time for a defrost cycle to occur.

The controller 10 waits for the compressor thermostat 18 to open, shutting the compressor 12 off at time 64. At the same time 64, a relay is switched to a defrost mode which, among other things, keeps the compressor 12 from turning back on. Subsequently, the controller pauses for a period of time 66 to allow evaporation of the refrigerant just compressed into liquid by the action of the compressor.

Once enough heat is absorbed by the refrigerant to re-close the compressor thermostat 18 at time 68, the defrost heater 14 is powered. The defrost heater 14 remains on for period of time, or the defrost period, T until the defrost termination thermostat 16 turns off the heater 14.

Following the termination of the heater 14, the controller 10 waits for a predetermined "drip time" 70 and then resumes normal compressor operation 72.

In the present embodiment, the adaptive defrost controller 10 is an electronic controller. If power to the controller 10

is interrupted for more than a few seconds, a memory circuit contained therein resets to a condition as though it had not been powered previously. Therefore, the information or data necessary for the adaptive defrost controller to operate as desired is lost. For instance, a brief power failure may interrupt a defrost cycle after the defrost heater 14 has been initiated. When power is restored, the adaptive defrost controller 10 would reset, returning to step 30 (FIG. 3) and defrosting would not resume until the defrost interval, X, has again elapsed. This could result in poor cooling performance due to the unintended extended time interval between defrosts.

The defrost termination thermostat 16 of the present embodiment is of a type which operates regardless of power interruption, such as a mechanical thermostat. Therefore, the termination thermostat 16 can be used by the adaptive defrost controller as a power independent memory device. For this purpose, the controller 10 checks the condition of the termination thermostat 16 upon the initial application of power. If the termination thermostat 16 is open, the appliance is presumed to be operating from a warm or newly uncrated condition. In this case, the controller 10 starts the compressor 12 and begins normal adaptive defrost control.

If the termination thermostat 16 is closed upon the application of power to the adaptive defrost controller 10, the appliance is in a cold state and a temporary power outage condition is presumed. In this case, the compressor 12 is run for a shortened interval followed by a defrost cycle. Following this shortened defrost interval, normal adaptive defrost control is resumed.

It should be evident that this disclosure is by way of example and that various changes may be made by adding, modifying or eliminating details without departing from the fair scope of the teaching contained in this disclosure. The invention is therefore not limited to particular details of this disclosure except to the extent that the following claims are necessarily so limited.

What is claimed is:

1. A method for defrosting a household refrigeration appliance including a compressor and a refrigeration compartment having a door, said method comprising the steps of:
  - setting a defrost interval (X) to an predetermined initial value ( $X_{initial}$ );
  - initiating a defrost cycle after the defrost interval has elapsed and the compressor is not running;
  - after initiating said defrost cycle, terminating said defrost cycle as determined by a defrost termination thermostat, the period between initiating and terminating the defrost cycle being referred to as a defrost time (T);
  - decreasing said defrost interval (X) by a set amount if said defrost time (T) is greater than a set ideal maximum defrost time ( $T_{range, max}$ ); and
  - increasing said defrost interval (X) by a set amount if said defrost time (T) is less than a set ideal minimum defrost time ( $T_{range, min}$ ).
2. The method of claim 1, wherein the defrost interval (X) can be decreased to no less than the initial value ( $X_{initial}$ ).
3. The method of claim 1, wherein the defrost interval (X) can be increased to more than a predetermined maximum defrost interval value ( $X_{max}$ ).
4. The method of claim 1, further comprising a step of engaging a vacation mode if the defrost interval (X) is equal to the maximum defrost interval ( $X_{max}$ ) and if the door has not been open for at least a predetermined vacation period.
5. The method of claim 4, further comprising a first vacation mode exit step performed following the engaging

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of the vacation mode if the door is opened, said vacation mode exit step comprising disengaging the vacation mode and running the defrost heater for a predetermined vacation exit period.

6. The method of claim 4, further comprising a vacation mode exit step performed following the engaging of the vacation mode if the defrost time (T) is not less than the ideal maximum defrost time ( $T_{range,max}$ ), said vacation mode exit step comprising disengaging the vacation mode and then performing said steps of setting and initiating.

7. The method of claim 1, further comprising a step of pausing for a defrost delay after the defrost interval has lapsed and after the compressor has stopped before initiating a defrost cycle.

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8. The method of claim 7, wherein the defrost delay ends when the compressor thermostat indicates that cooling is required.

9. The method of claim 1, further comprising a step of pausing for a drip time following the termination of the defrost cycle before allowing the compressor to run at the demand of the compressor thermostat.

10. The method of claim 1, further comprising a step performed after the step of initiating the defrost cycle of immediately terminating the defrost cycle once a predetermined absolute maximum defrost time ( $T_{max}$ ) has elapsed and then immediately allowing the compressor to run at the demand of the compressor thermostat.

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